



SUPERGEN Wind
Wind Energy Technology

Session 3: Offshore Wind Resource

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SUPERGEN Wind Energy Technologies Consortium Phase 2
2nd Training Seminar, University of Manchester
24th - 25th March 2011



Introduction

- The challenge of offshore wind resource assessment
- Offshore meteorology
- Measuring offshore wind
- Methods to predict offshore wind resource

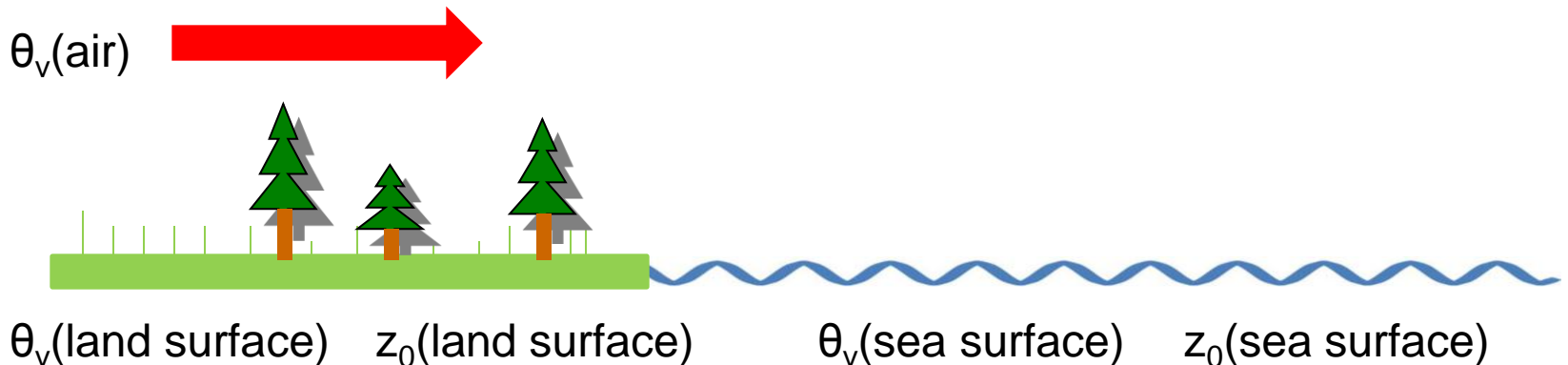
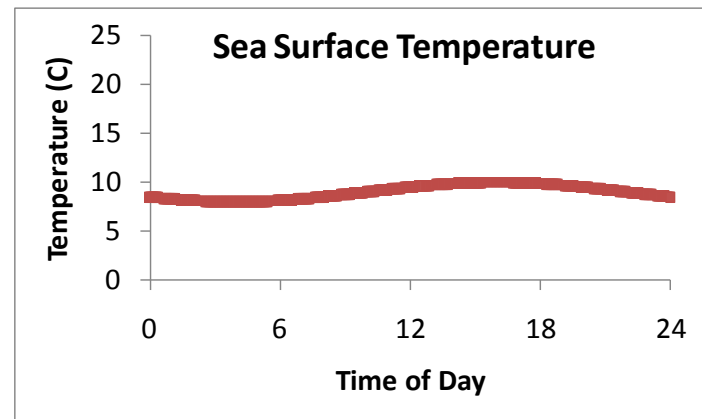
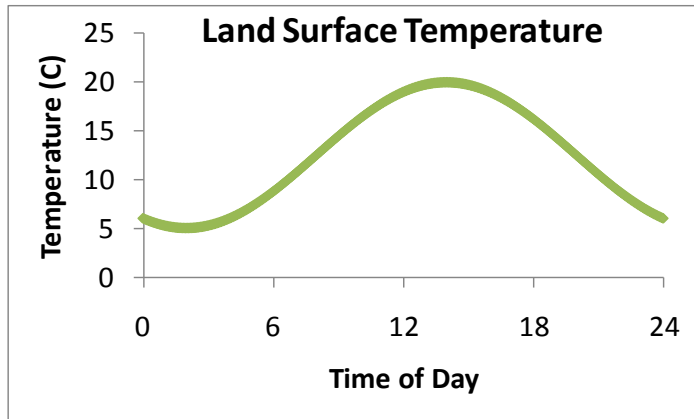


The Offshore Challenge



- Lack of wind speed data
- Expensive to measure
- Wind flow complicated by land/sea effects

Offshore Meteorology



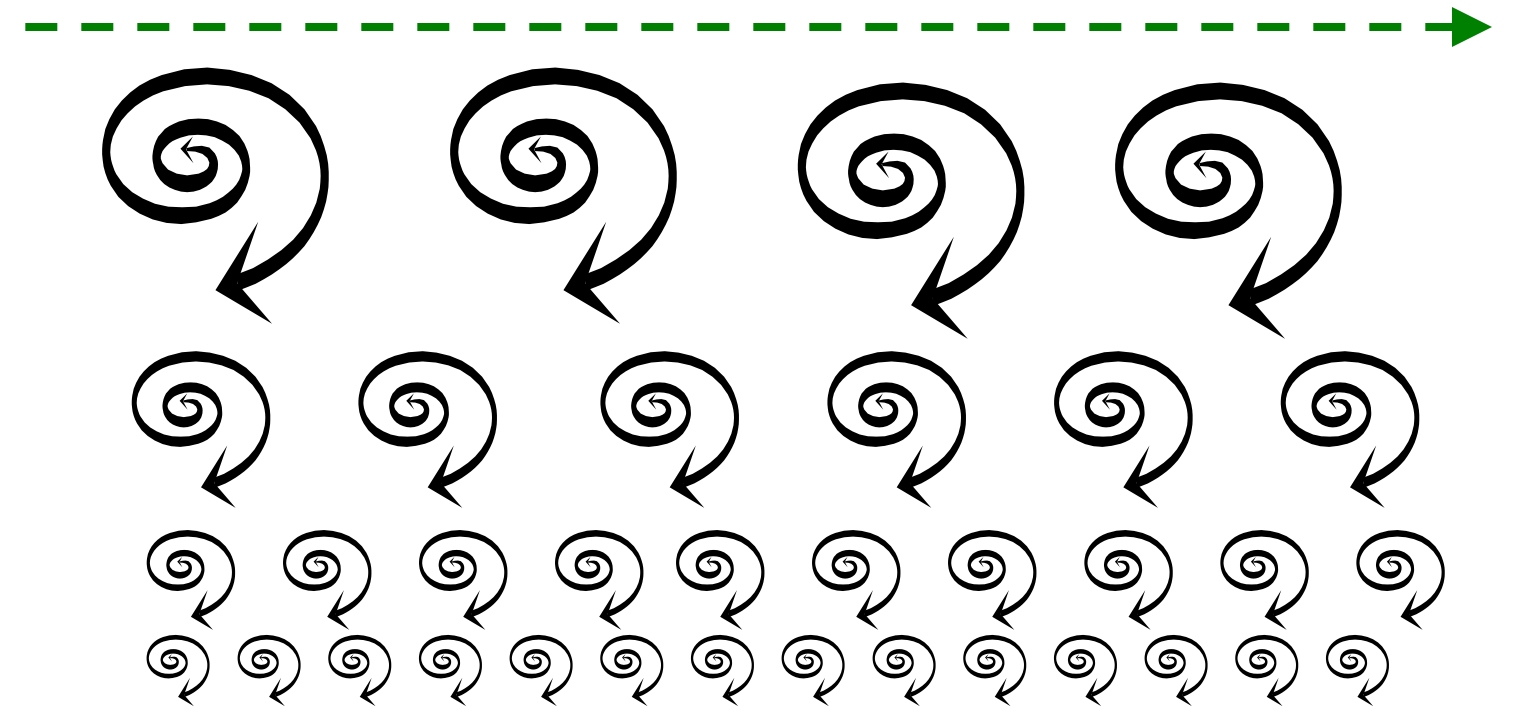
$$\theta_v(\text{air}) \approx \theta_v(\text{land surface})$$

$$\theta_v(\text{air}) \neq \theta_v(\text{sea surface})$$

$$z_0(\text{land surface}) \gg z_0(\text{sea surface})$$

Momentum Transfer to the Surface

Free Atmosphere



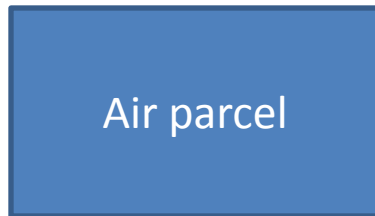
Surface

*Momentum flux depends on surface roughness,
temperature gradient and surface heating/cooling*



Atmospheric Stability

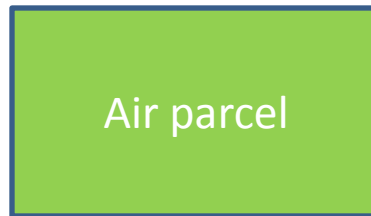
Assumed most dominant state onshore where $u > 6\text{m/s}$



Air parcel

Stable

$$\frac{\partial \theta_v}{\partial z} > 0$$



Air parcel

Neutral

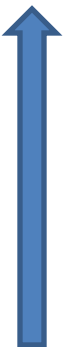
$$\frac{\partial \theta_v}{\partial z} = 0$$



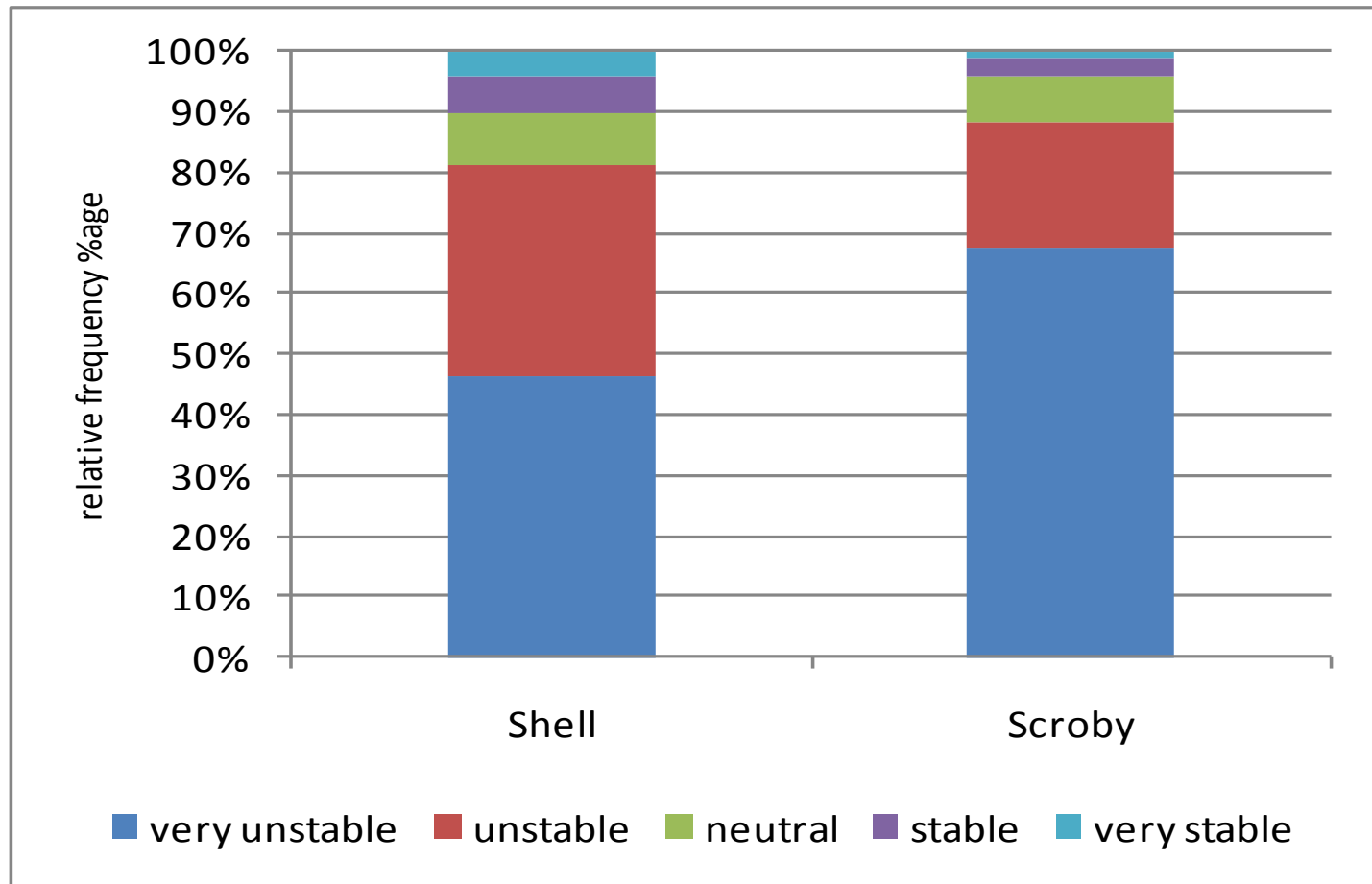
Air parcel

Unstable

$$\frac{\partial \theta_v}{\partial z} < 0$$



Stability at Two Offshore Sites



If neutral were the most dominant state when $u > 6\text{m/s}$, then conditions would be neutral ~70% of the time offshore typically...

Vertical Wind Speed Profile

Friction velocity

Wind speed

Height

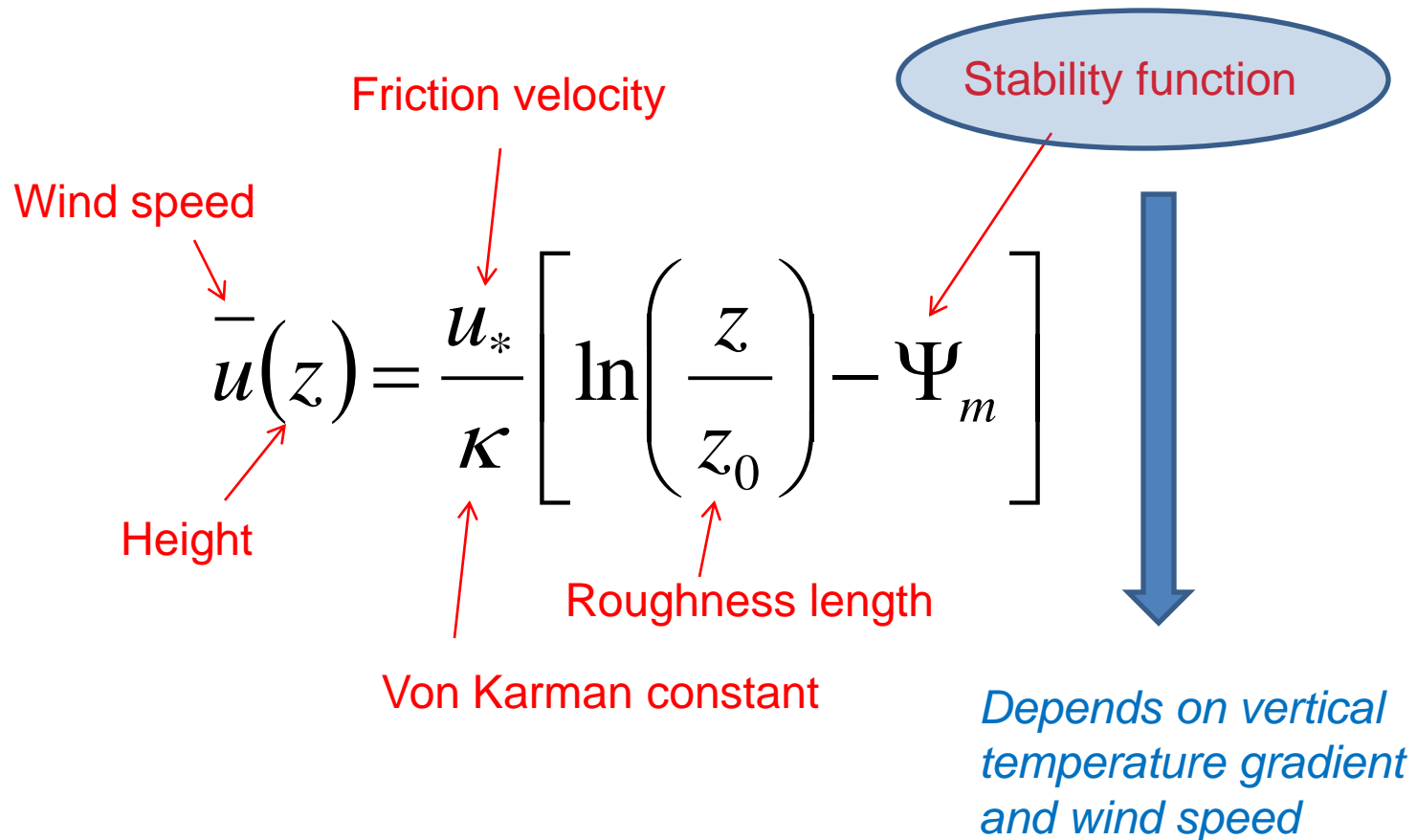
Von Karman constant

Roughness length

Stability function

$$\bar{u}(z) = \frac{u_*}{K} \left[\ln \left(\frac{z}{z_0} \right) - \Psi_m \right]$$

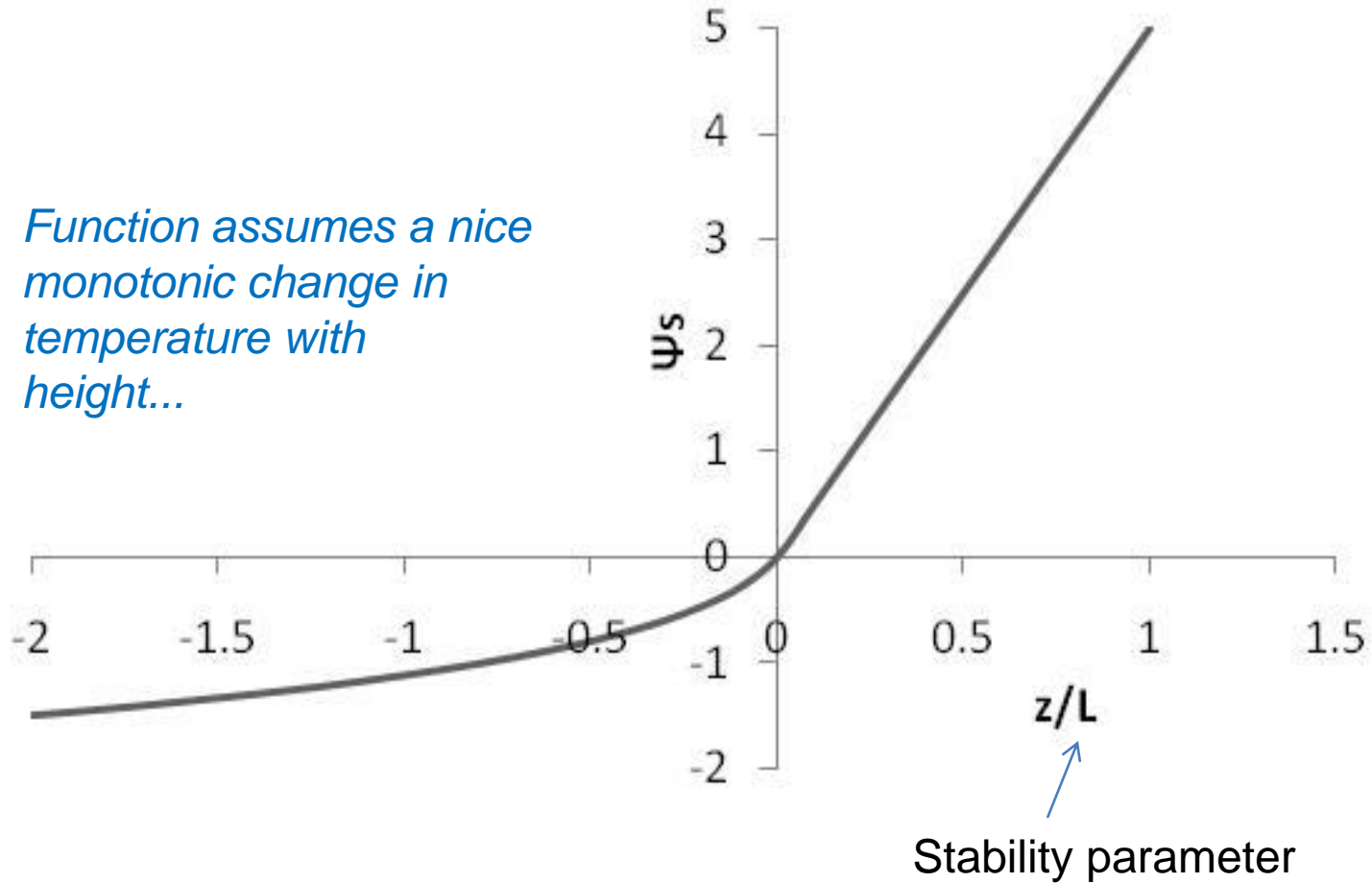
Depends on vertical temperature gradient and wind speed



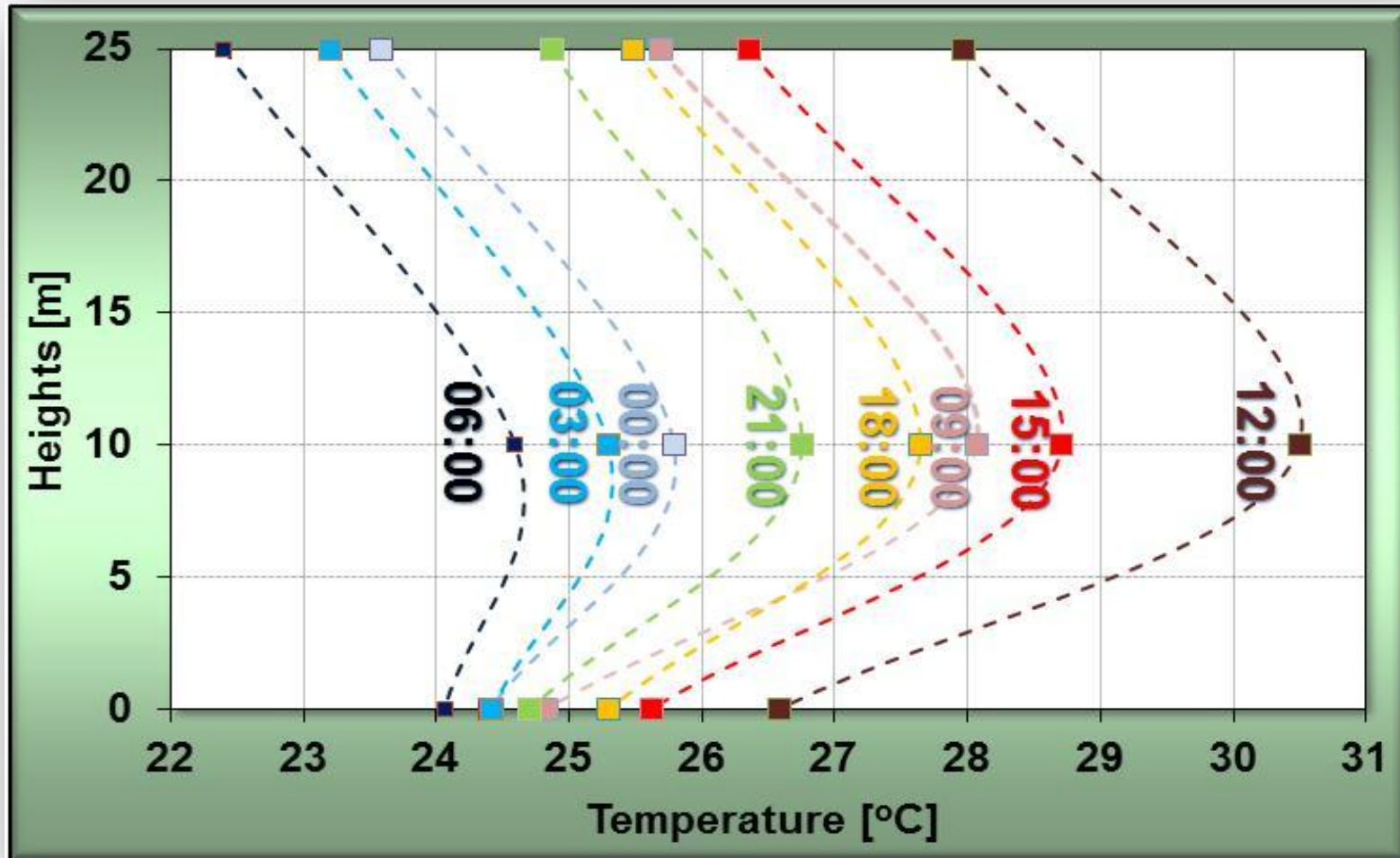
The diagram illustrates the vertical wind speed profile equation. The equation is $\bar{u}(z) = \frac{u_*}{K} \left[\ln \left(\frac{z}{z_0} \right) - \Psi_m \right]$. Red arrows point from labels to the corresponding terms: 'Wind speed' points to $\bar{u}(z)$, 'Height' points to z , 'Friction velocity' points to u_* , 'Von Karman constant' points to K , and 'Roughness length' points to z_0 . The term Ψ_m is enclosed in a blue oval labeled 'Stability function'. A large blue arrow points downwards from this oval, with the text 'Depends on vertical temperature gradient and wind speed' written in blue below it.

Stability Function

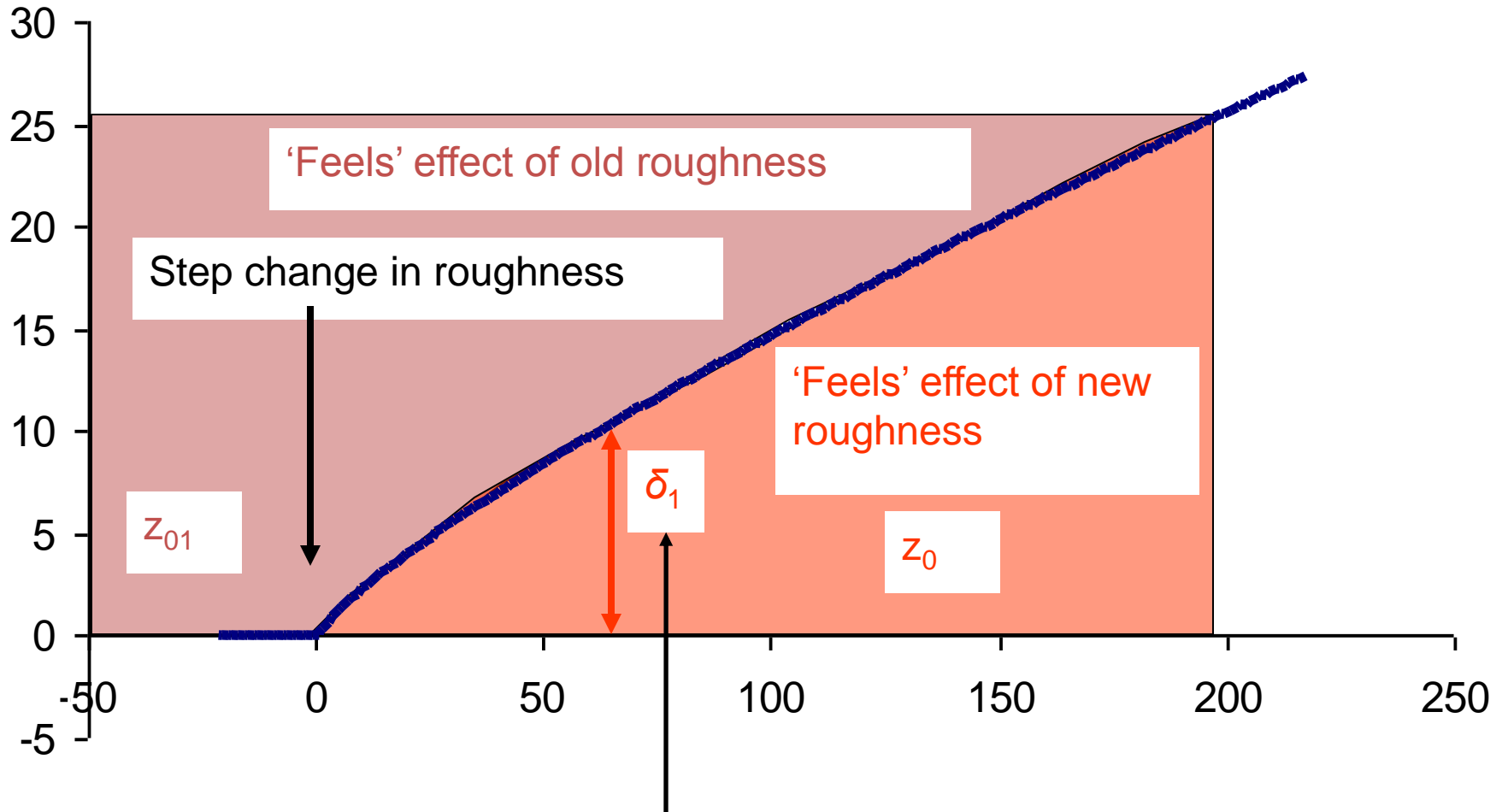
*Function assumes a nice
monotonic change in
temperature with
height...*



Vertical Temperature Profiles Rarely Monotonic

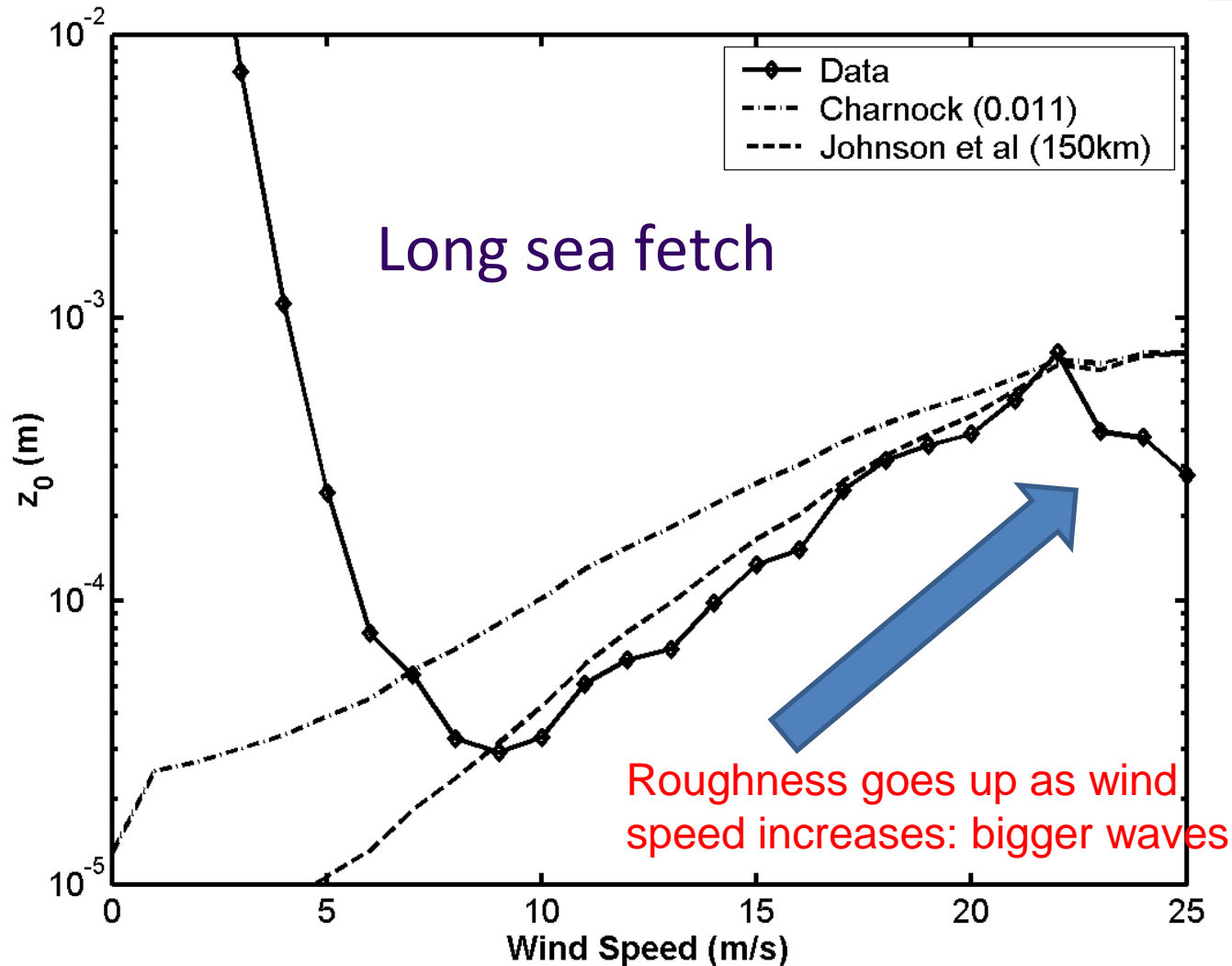


Internal Boundary Layer

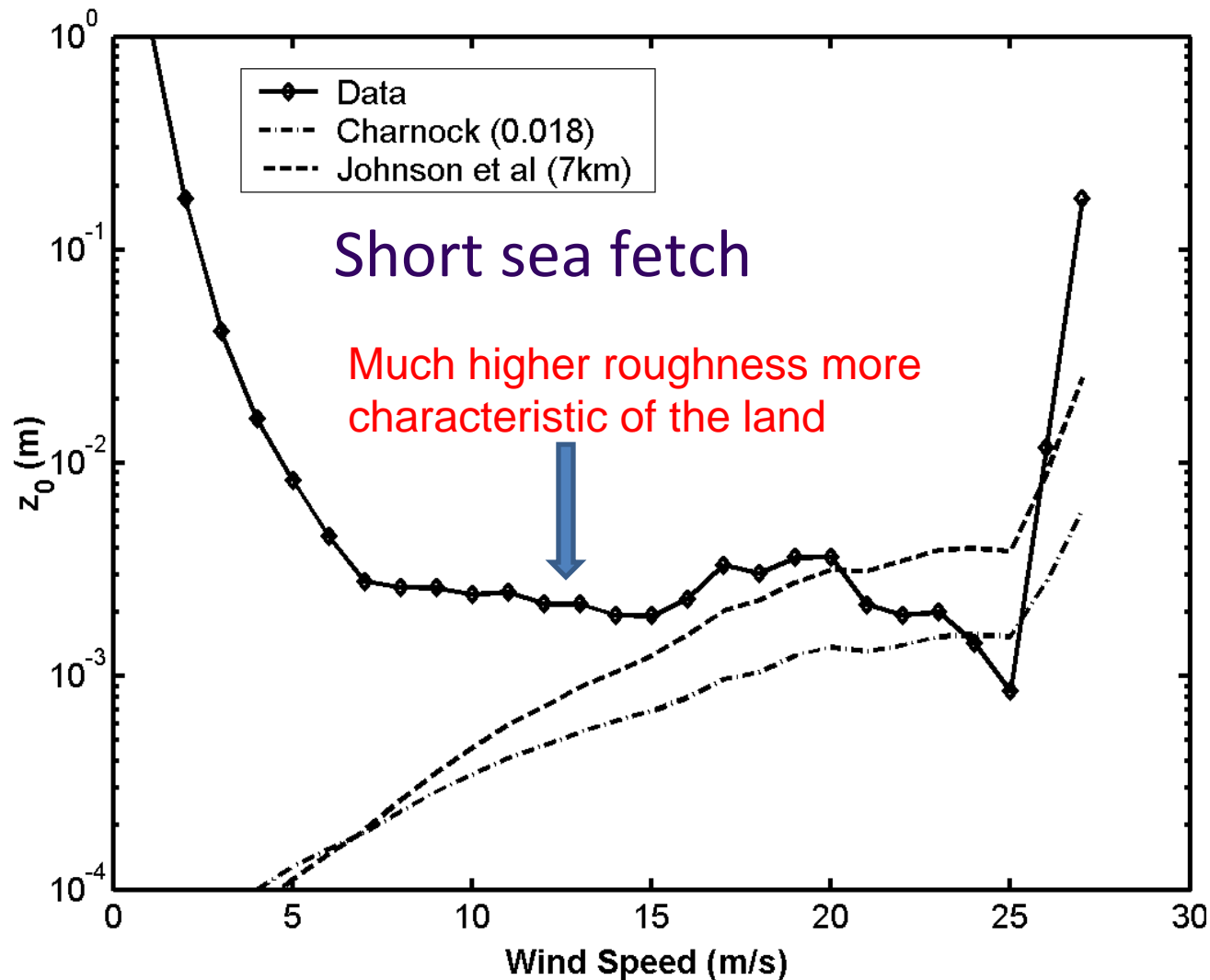


Function of roughness change and stability

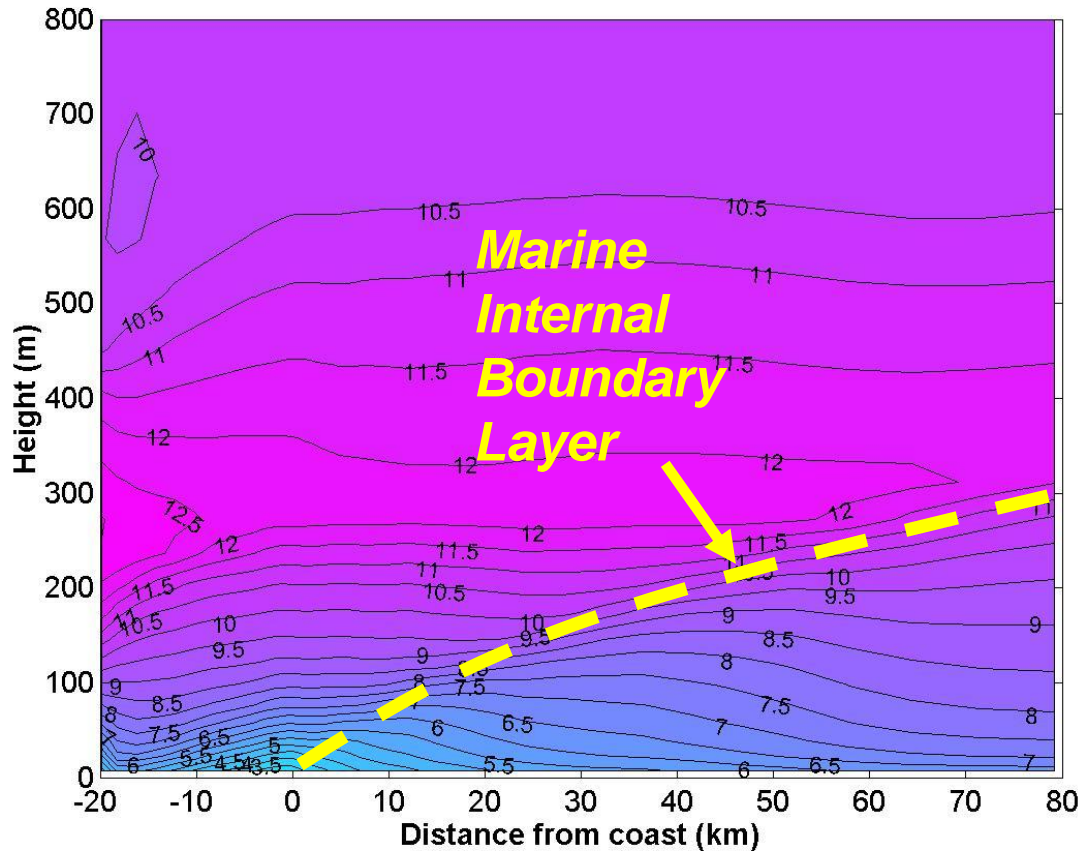
Sea Surface Roughness...



...Fetch Dependence



Wind Flow Offshore

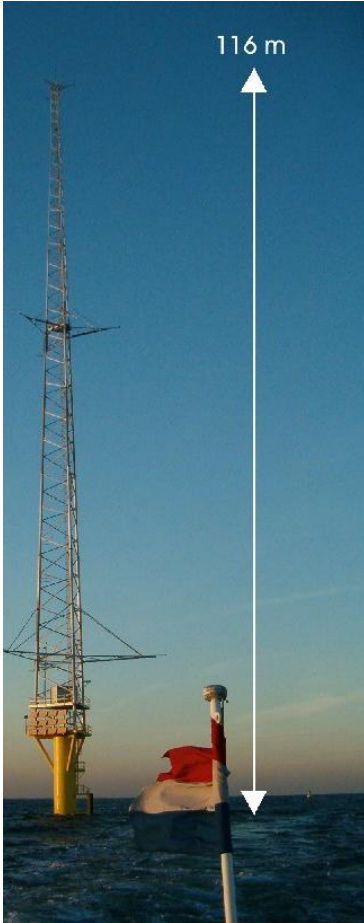


- Wind adjusting to new surface
- Very different thermal properties
- Time varying
- Need to model roughness change and thermal effects



Measuring Offshore Winds

Offshore Masts



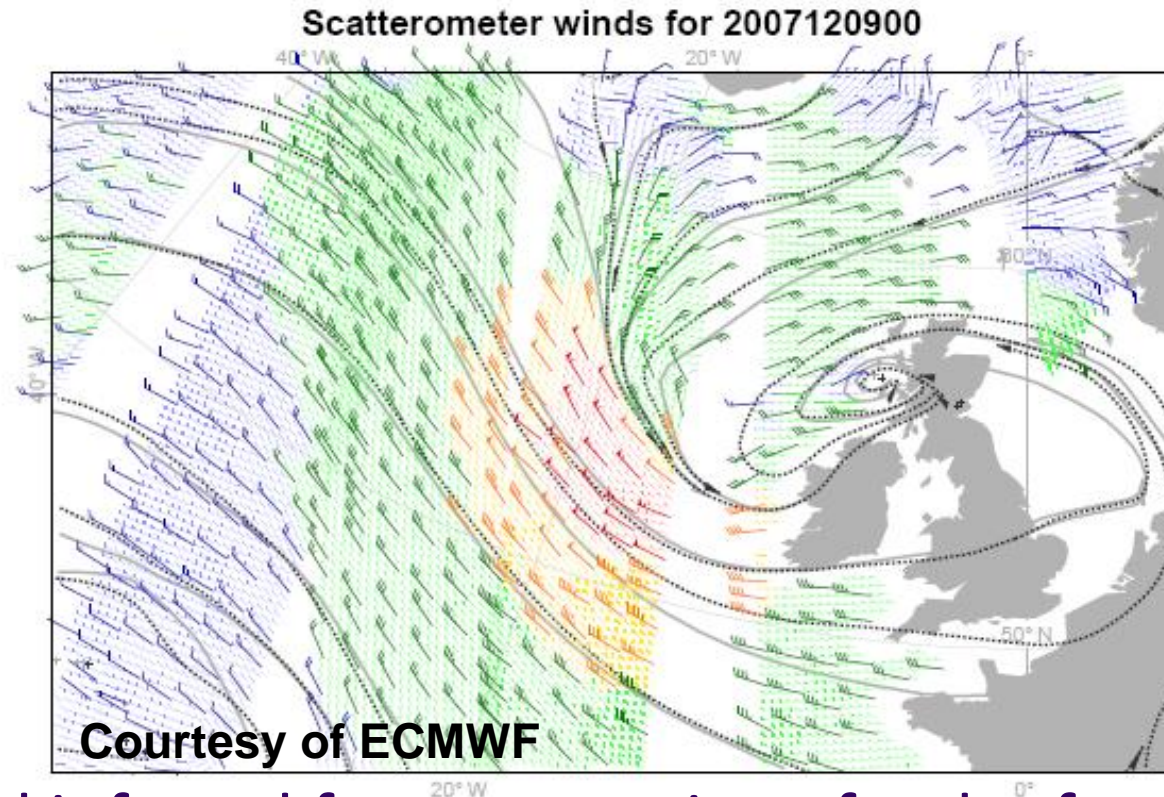
- Mast measurements well understood
- Mount instruments at several heights
- Flow distortion
- Increasing size...
- Increasing cost ~ £5M!

LIDAR (Light Detection And Ranging)



- Uses laser pulses to measure wind speed
- Portable, measurements at multiple heights
- Accurate in flat terrain such as at sea

Satellite Data



- Wind inferred from scattering of radar from waves
- Wide area coverage but limited radar passes
- Accuracy questionable near coasts

Ships and Buoys



- Widespread measurements
- Quality variable
- How to correct for motion



Predicting Offshore Wind Resource

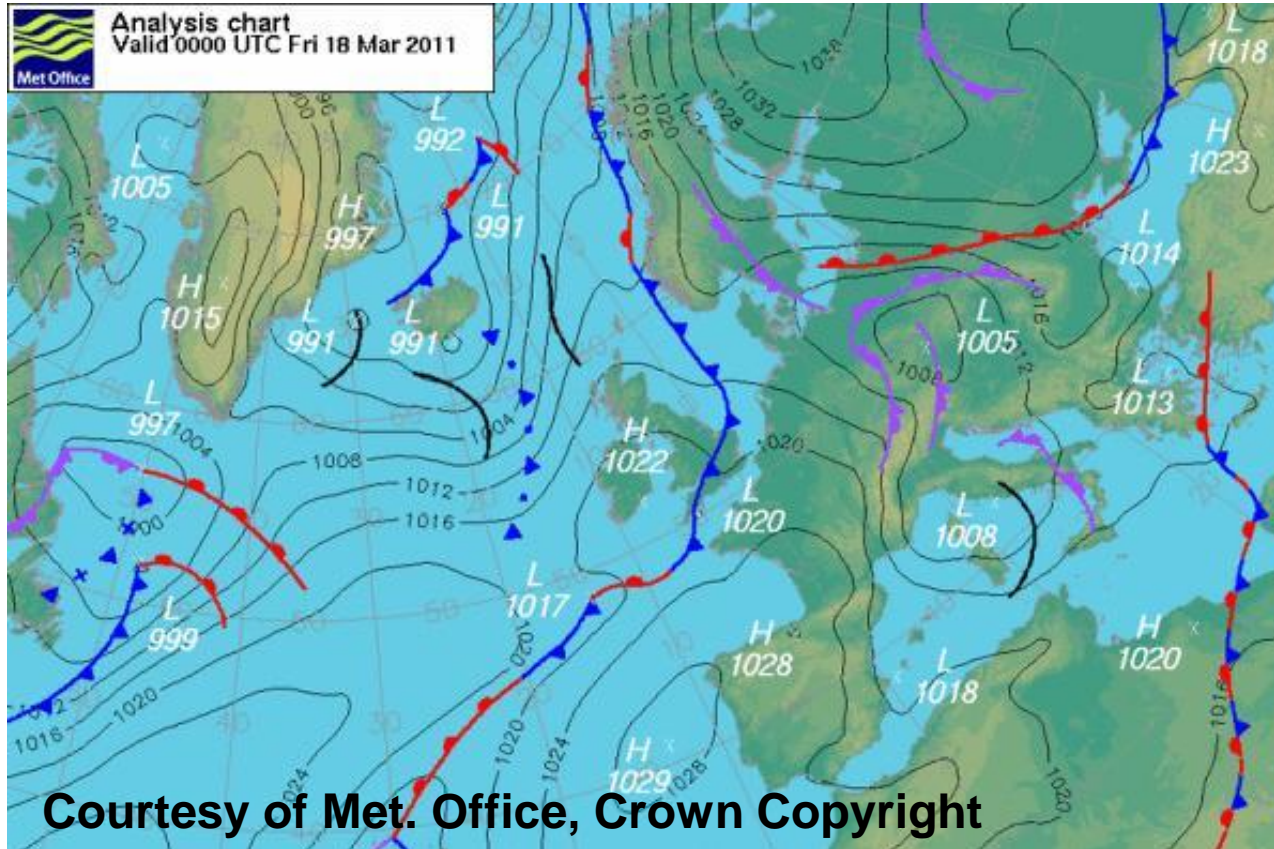


Simple Linear Function of Onshore Wind Speed



$$u_{sea}(10m) = 1.62 + 1.17u_{land}(10m)$$

Pressure Data



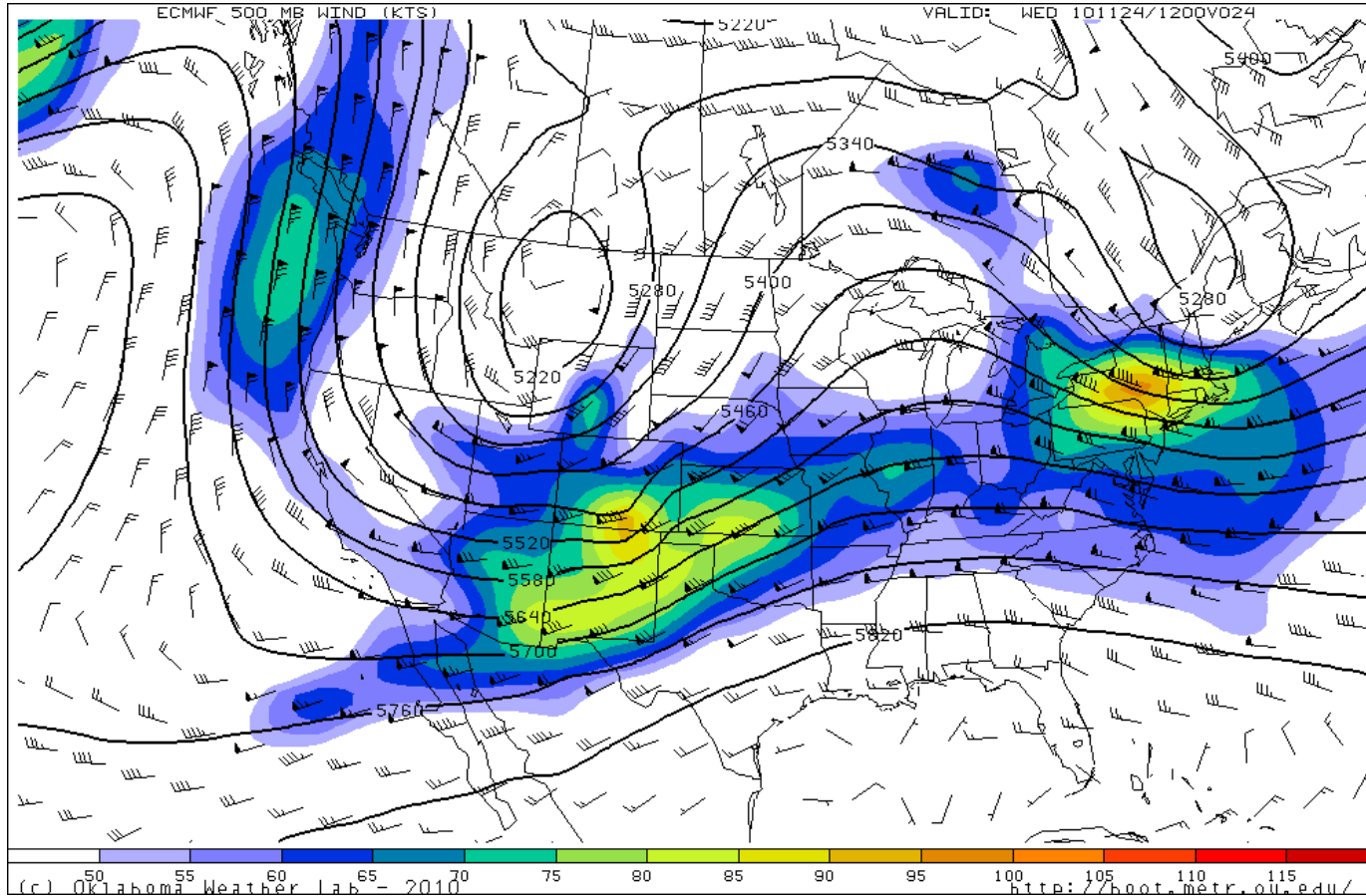
Geostrophic wind

Geostrophic drag law

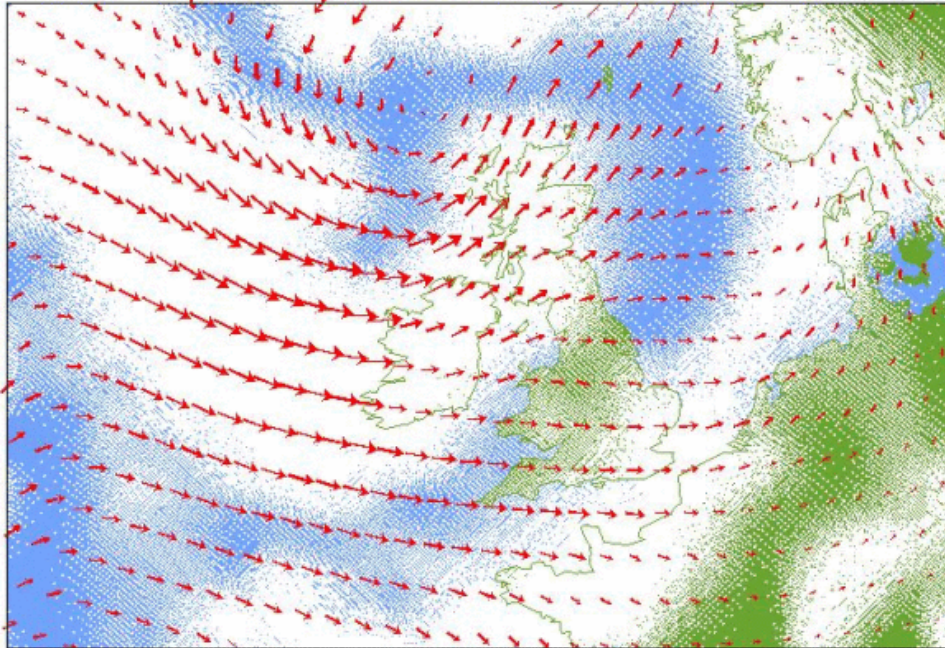
Surface wind



Numerical Weather Prediction (NWP) Models



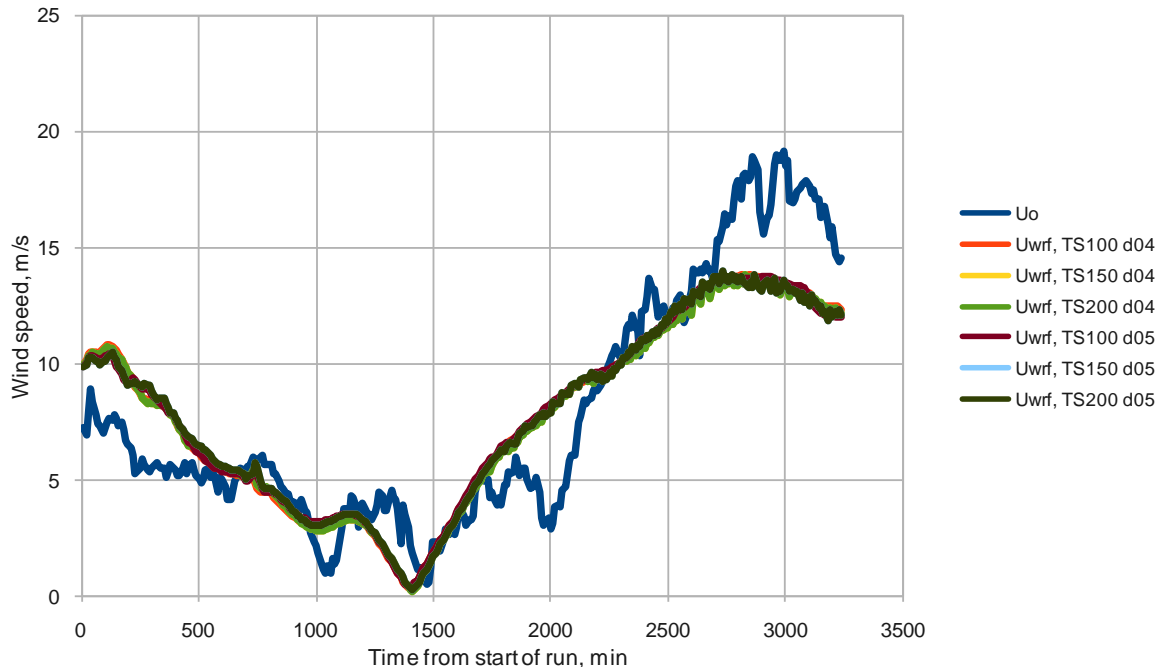
Reanalysis Datasets



- ERA-40, NCEP/NCAR
- Meteorological data 'homogenised' on regular grid
- Long term >40 years
- Resolution coarse, 6 hourly values

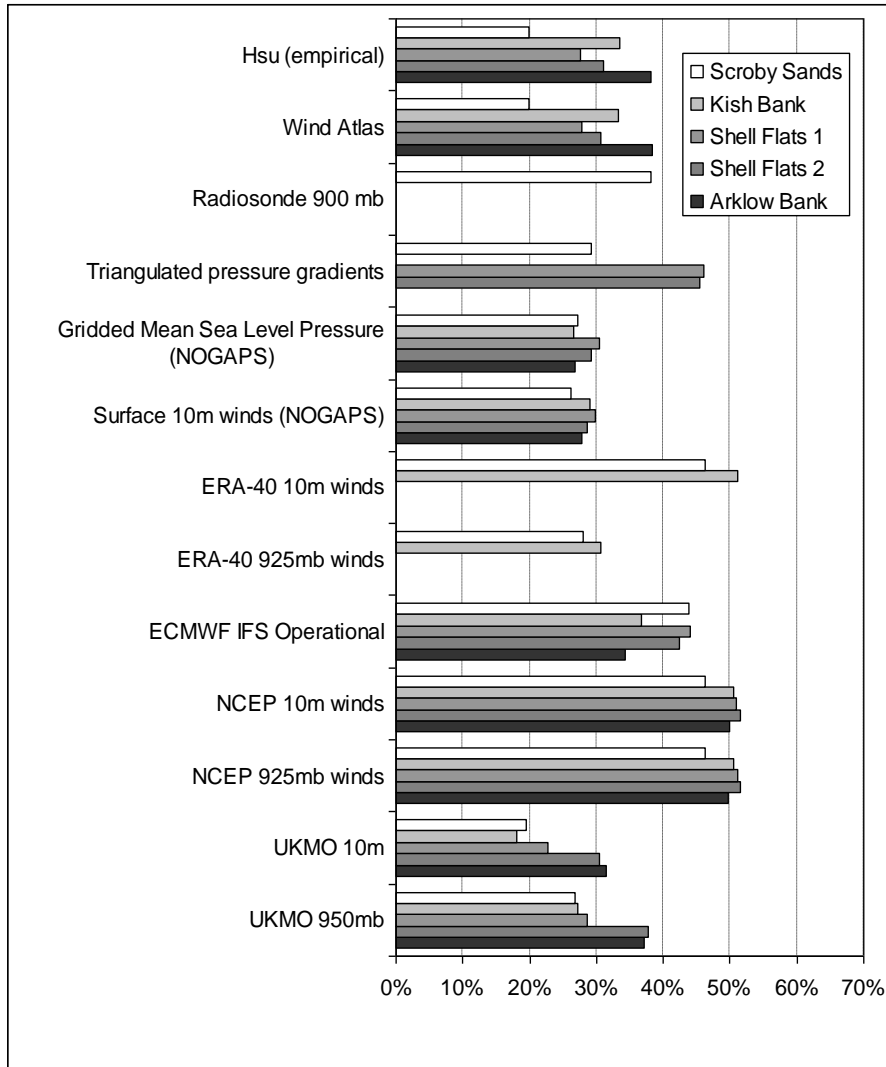
Mesoscale Models, e.g. WRF

Time Series Day 39
Observed versus WRF Output 33m AMSL



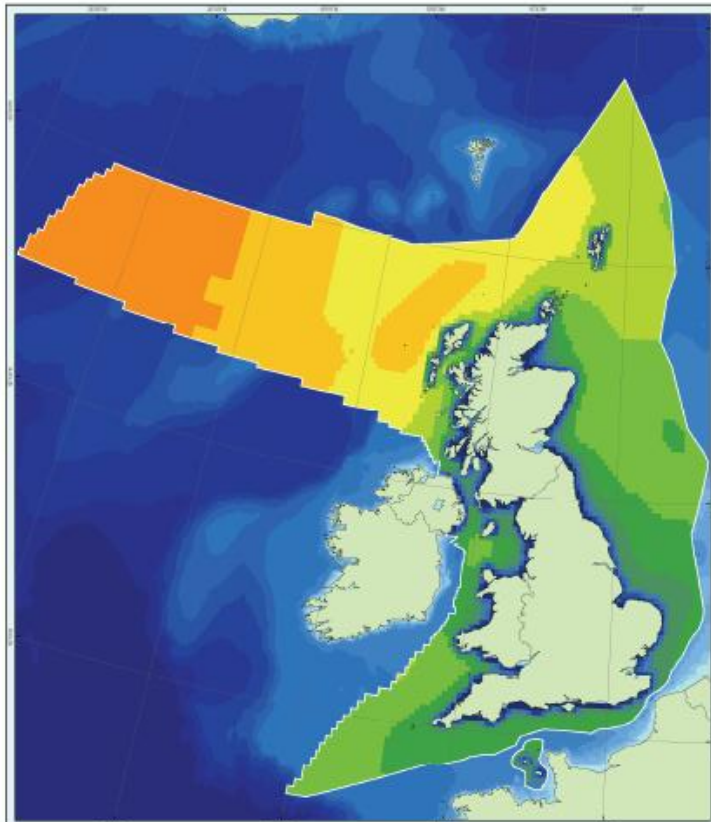
- Land/sea wind simulation
- Useful tool for simulating dynamic situation with temperature dependence
- Issues with wind close to the ground

Some Comparisons



- Met. Office forecasts perform well
- Lowest rms errors 20-25%

Offshore Wind Speed Atlas 100m amsl

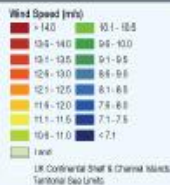


Annual Mean Wind Speed at 100m

Projection
Scale
Map Designed and Produced by MRFW

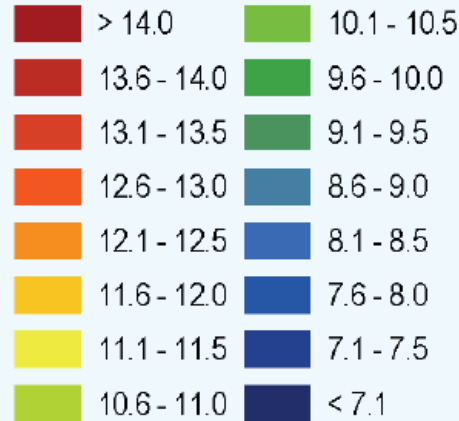
Atlas of UK Marine Renewable Energy Resources

1. North of 60° N and West of 12° W, model cell size approximately 60km. Model cell size approximately 12km in all other areas.
2. Modelled wind data will be less robust at local sea boundary points.
3. Wind data are based on hourly model forecast values over 7 years.
4. Wind speed at 100 metres above sea level.
5. March 2010, Version 2.0.
6. © Crown copyright. All rights reserved.



- Based on Met. Office Global and Mesoscale Models outputs
- ~12km resolution, except NW 'spur' (~60km)

Wind Speed (m/s)





Summary

- Paucity of quality measured offshore wind data
- Land/sea transition and different thermal properties make modelling wind profile offshore challenging
- A variety of different methods for measuring wind speed – more remote sensing data becoming available
- A variety of models that can be used for predicting offshore winds but an area of much research – offshore wakes also!